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# Wind turbine

## A wind turbine is a device that converts the wind's kinetic energy into electrical energy.

From Wikipedia, the δωρεάν encyclopedia

This article is about wind-powered electrical generators. For wind-powered machinery used to grind grain or pump water, see Windmill and Windpump.

Offshore wind farm, using 5 MW turbines REpower 5M in the North Sea off the coast of Belgium.

Part of a series on

Renewable energy

Biofuel Biomass Geothermal Hydropower Solar energy Tidal power Wave power Wind power

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A wind turbine is a device that converts the wind's kinetic energy into electrical energy.

Wind turbines vary vastly in size, shape, and orientation. Small turbines are used for a variety of rudimentary applications, while πελώριες turbines are often found in wind farms and provide power to the electric grid. Wind was shown to have the "lowest relative greenhouse gas emissions, the least water consumption demands and cause far less environmental damage than other current energy providers, such as fossil fuels.[1]

# History

## Main article: History of wind power

## James Blyth's electricity-generating wind turbine, photographed in 1891

Wind power was probably used in Persia (present-day Iran) about 500–900 AD.[2] The windwheel of Hero of Alexandria marks one of the αρχικός recorded instances of wind powering a machine in history.[3][4] However, the first known practical wind power plants were built in Sistan, an Eastern province of Iran, from the 7th century. These "Panemone" were vertical axle windmills, which had long κατακόρυφος drive shafts with rectangular blades.[5] Made of six to twelve sails covered in reed matting or cloth material, these windmills were used to grind grain or draw up water, and were used in the gristmilling and sugarcane industries.[6]

Wind power first appeared in Europe during the Middle Ages. The first historical records of their use in England date to the 11th or 12th centuries and there are reports of German crusaders taking their windmill-making skills to Syria around 1190.[7] By the 14th century, Dutch windmills were in use to drain areas of the Rhine delta. Advanced wind turbines were described by Croatian inventor Fausto Veranzio. In his book Machinae Novae (1595) he described vertical axis wind turbines with curved or V-shaped blades.

The first electricity-generating wind turbine was a battery charging machine installed in July 1887 by Scottish academic James Blyth to light his holiday home in Marykirk, Scotland.[8] Some months later American inventor Charles F. Brush was able to build the first automatically operated wind turbine after consulting local University professors and colleagues Jacob S. Gibbs and Brinsley Coleberd and successfully getting the blueprints peer-reviewed for electricity production in Cleveland, Ohio.[8] Although Blyth's turbine was considered uneconomical in the United Kingdom[8] electricity generation by wind turbines was more cost effective in countries with widely scattered populations.[7]

The first automatically operated wind turbine, built in Cleveland in 1887 by Charles F. Brush. It was 60 feet (18 m) tall, weighed 4 tons (3.6 metric tonnes) and powered a 12 kW generator.[9]

In Denmark by 1900, there were about 2500 windmills for mechanical loads such as pumps and mills, producing an estimated combined peak power of about 30 MW. The largest machines were on 24-meter (79 ft) towers with four-bladed 23-meter (75 ft) diameter rotors. By 1908 there were 72 wind-driven electric generators operating in the United States from 5 kW to 25 kW. Around the time of World War I, American windmill makers were producing 100,000 farm windmills each year, mostly for water-pumping.[10]

By the 1930s, wind generators for electricity were common on farms, mostly in the United States where distribution systems had not yet been installed. In this period, high-tensile steel was cheap, and the generators were placed atop prefabricated open steel lattice towers.

A forerunner of modern horizontal-axis wind generators was in service at Yalta, USSR in 1931. This was a 100 kW generator on a 30-meter (98 ft) tower, connected to the local 6.3 kV distribution system. It was reported to have an annual capacity factor of 32 percent, not much different from current wind machines.[11]

In the autumn of 1941, the first megawatt-class wind turbine was synchronized to a utility grid in Vermont. The Smith-Putnam wind turbine only ran for 1,100 hours before suffering a critical failure. The unit was not repaired, because of shortage of materials during the war.

The first utility grid-connected wind turbine to operate in the UK was built by John Brown & Company in 1951 in the Orkney Islands.[8][12]

Despite these diverse developments, developments in fossil fuel systems almost entirely eliminated any wind turbine systems larger than supermicro size. In the early 1970s, however, anti-nuclear protests in Denmark spurred artisan mechanics to develop microturbines of 22 kW. Organizing owners into associations and co-operatives lead to the lobbying of the government and utilities and provided incentives for larger turbines throughout the 1980s and later. Local activists in Germany, nascent turbine manufacturers in Spain, and large investors in the United States in the early 1990s then lobbied for policies that stimulated the industry in those countries. Later companies formed in India and China. As of 2012, Danish company Vestas is the world's biggest wind-turbine manufacturer.

# Resources

## Main article: Wind power

## Animation of wind turbine

A quantitative measure of wind energy available at any location is called the Wind Power Density (WPD). It is a calculation of the mean annual power available per square meter of swept area of a turbine, and is tabulated for different heights above ground. Calculation of wind power density includes the effect of wind velocity and air density. Color-coded maps are prepared for a particular area described, for example, as "Mean Annual Power Density at 50 Metres". In the United States, the results of the above calculation are included in an index developed by the National Renewable Energy Laboratory and referred to as "NREL CLASS". The higher the WPD, the higher its class, which range from Class 1 (200 watts per square meter or less at 50 m altitude) to Class 7 (800 to 2000 watts per square m). Commercial wind farms generally are sited in areas with resource of Class 3 or higher, although isolated points in an otherwise Class 1 area may be practical to exploit.[13]

Complex Table(less accessible)

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# lifecycle_apple.gifEfficiency

## Betz's law

Conservation of mass requires that the amount of air entering and exiting a turbine must be equal. Accordingly, Betz's law gives the maximal achievable extraction of wind power by a wind turbine as 16/27 (59.3%) of the total kinetic energy of the air flowing through the turbine.[15]

The maximum theoretical power output of a wind machine is thus 16/27 times the kinetic energy of the air passing through the effective disk area of the machine. If the effective area of the disk is A, and the wind velocity v, the maximum theoretical power output P is:

P = 16 27 1 2 ρ v 3 A = 8 27 ρ v 3 A {\displaystyle P={\frac {16}{27}}{\frac {1}{2}}\rho v^{3}A={\frac {8}{27}}\rho v^{3}A} {\displaystyle P={\frac {16}{27}}{\frac {1}{2}}\rho v^{3}A={\frac {8}{27}}\rho v^{3}A},

where ρ is the air density.

As wind is free (no fuel cost), wind-to-rotor efficiency (including rotor blade friction and drag) is one of many aspects impacting the final price of wind power.[16] Further inefficiencies, such as gearbox losses, generator and converter losses, reduce the power delivered by a wind turbine. To protect components from undue wear, extracted power is held constant above the rated operating speed as theoretical power increases at the cube of wind speed, further reducing theoretical efficiency. In 2001, commercial utility-connected turbines deliver 75% to 80% of the Betz limit of power extractable from the wind, at rated operating speed.[17][18][needs update]

Efficiency can decrease slightly over time, one of the main reasons being dust and insect carcasses on the blades which alters the aerodynamic profile and essentially reduces the lift to drag ratio of the airfoil. Analysis of 3128 wind turbines older than 10 years in Denmark showed that half of the turbines had no decrease, while the other half saw a production decrease of 1.2% per year.[19] Vertical turbine designs have much lower efficiency than standard horizontal designs

# Types

## The three primary types: VAWT Savonius, HAWT towered; VAWT Darrieus as they appear in operation

Wind turbines can rotate about either a horizontal or a vertical axis, the former being both older and more common.[21] They can also include blades, or be bladeless.[22] Vertical designs produce less power and are less common. Large three-bladed horizontal-axis wind turbines (HAWT), with the blades upwind of the tower produce the overwhelming majority of windpower in the world today. These turbines have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a yaw system. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator.[24] Some turbines are direct-drive, meaning they couple the rotor directly to the generator with no gearbox in between.

Any solid object produces a wake behind it, leading to fatigue failures, so the turbine is usually positioned upwind of its supporting tower. Downwind machines have been built, because they don't need an additional mechanism for keeping them in line with the wind. In high winds, the blades can also be allowed to bend which reduces their swept area and thus their wind resistance. In upwind designs, turbine blades must be made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted forward into the wind a small amount.

Turbines used in wind farms for commercial production of electric power are usually three-bladed. These have low torque ripple, which contributes to good reliability. The blades are usually colored white for daytime visibility by aircraft and range in length from 20 to 80 meters (66 to 262 ft). The size and height of turbines increase year by year. Offshore wind turbines are built up to 8MW today and have a blade length up to 80 meters (260 ft). Usual tubular steel towers of multi megawatt turbines have a height of 70 m to 120 m and in extremes up to 160 m.

Η οικογένεια μου.